AGU Fall Meeting 2016

Hemispheric Differences in Tropical Lower Stratospheric Transport and Tracers Annual Cycle

A11U: Processes and Linkages in the Upper Troposphere and Lower Stratosphere: Observations and Models I

Olga Tweedy[1], D. Waugh[1], R. Stolarski[1,2], L. Oman[2]

1. Johns Hopkins University, Department of Earth and Planetary Sciences;

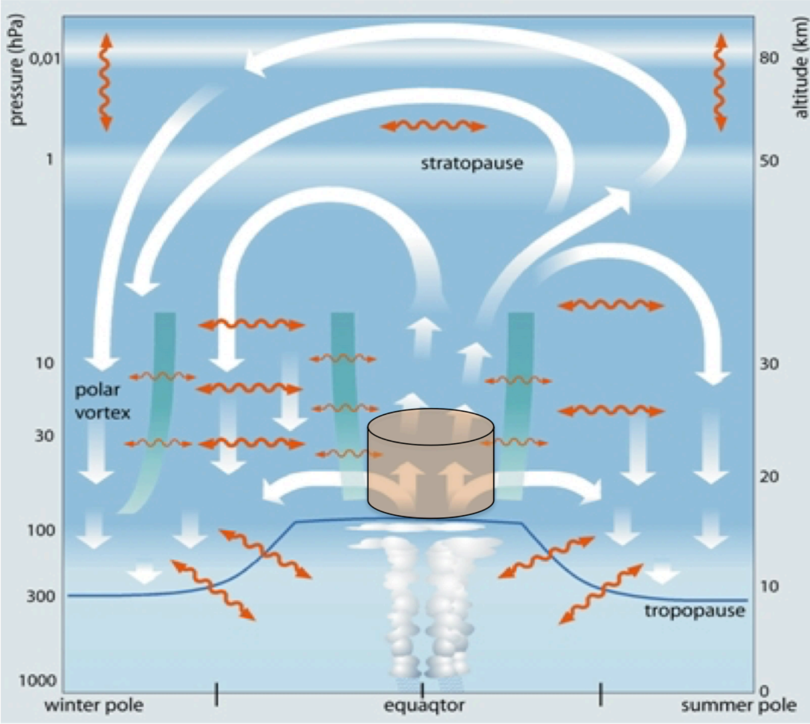
2. NASA Goddard Space Flight Center

Transport: Vertical advection vs quasi-horizontal mixing

The balance between upwelling and quasi-horizontal mixing in the tropical lower stratosphere is not well understood!

- Randel *et al.* [2007]: large seasonal cycle in upwelling is a response for seasonal changes in ozone.

- Abalos *et al*. [2012, 2013] and Ploeger *et al*. [2012] show the importance of eddy mixing



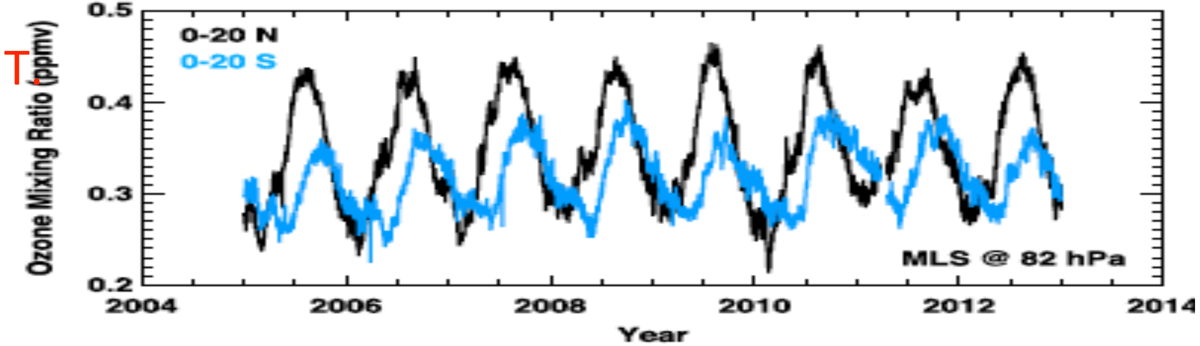
There studies have focused on variations in tracers and processes in the tropic-wide average (20°N-20°S), i.e. have considered "well-mixed" tropics.

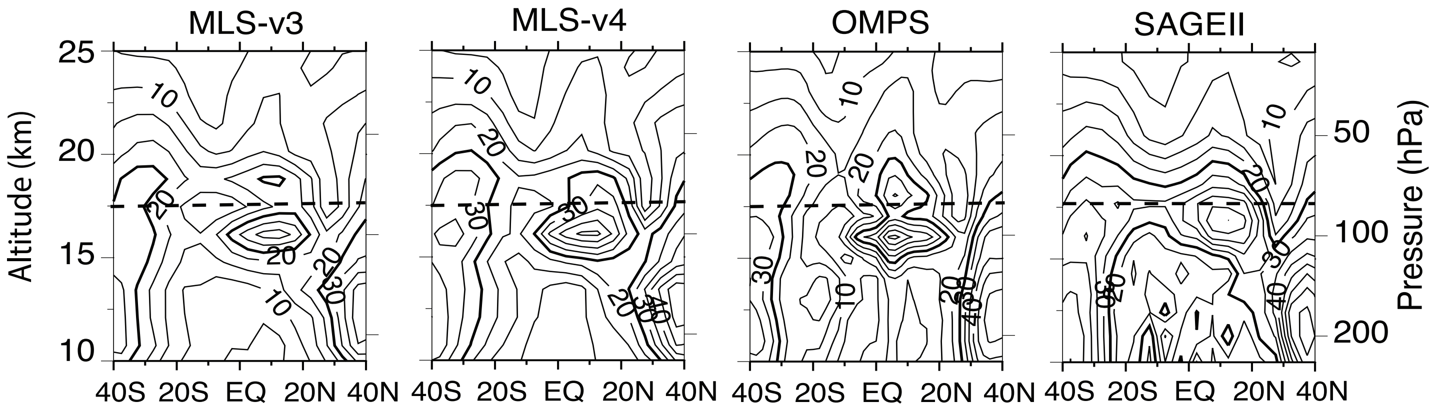
Hemispheric differences in ozone annual cycle

Southern tropics (ST) are different from Northern tropics (NT)

- Larger annual amplitude in NT.
- 2-3 month shift in phase.

[Stolarski et al., 2014]





Annual cycle amplitude of ozone (% relative to the mean) from satellite observations

MAIN QUESTIONS

1. Do Chemistry Climate Models (CCMs) capture the observed differences between the NT and ST?

2. What processes control the ST and NT annual cycles in the models?

CCMVal -2 MODELS

Model Simulations: 1960 to 2010 simulation of the models from CCMVal-2 multi-model intercomparison project

- 18 CCMs: all transient (historical) runs with nearly identical forcings (GHGs, ODSs, ect).

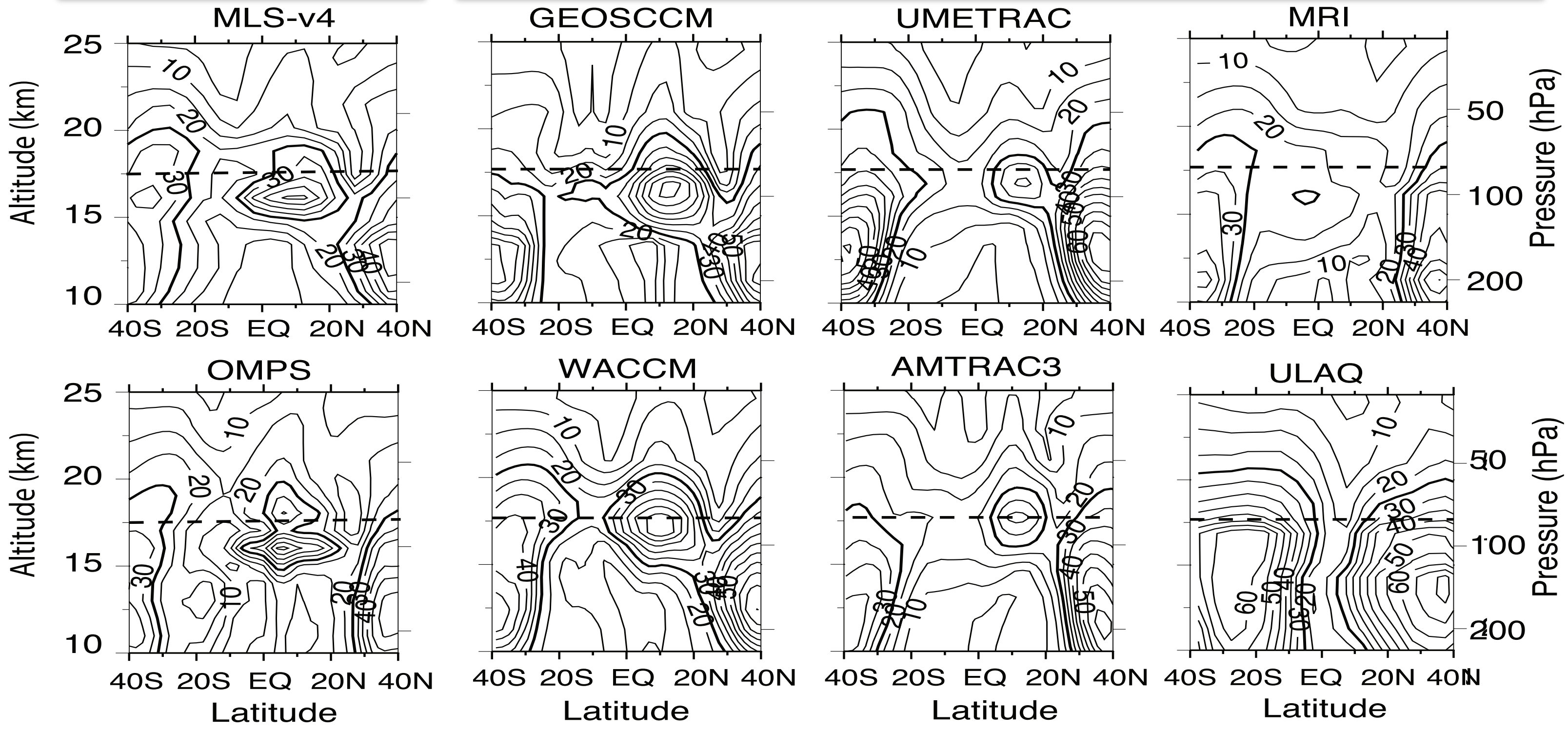
Satellite observations:

- Version 3 and 4 of the Aura Microwave Limb Sounder (**MLS**) [Livesey et al., 2008]
- the Ozone Mapping and Prole Suite (**OMPS**) on board NASA/NOAA Suomi-NPP satellite [Kramarova et al., 2014]
- the Stratospheric Aerosol and Gas Experiment II (**SAGEII**) [Wang et al., 2002]

Latitude-pressure variations in ozone seasonality

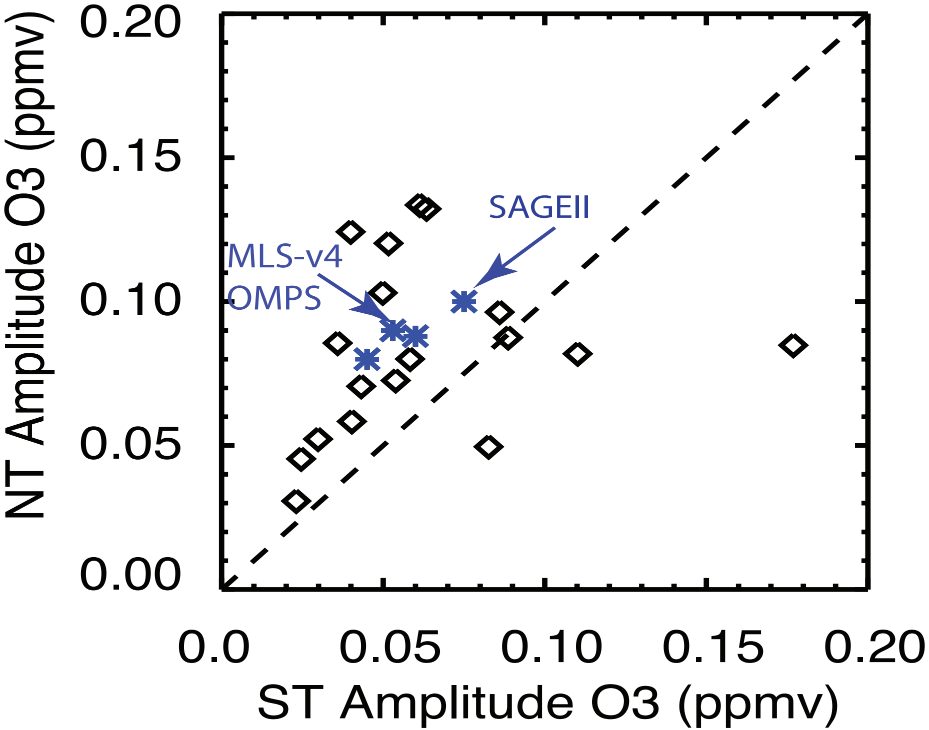
Observations

Models



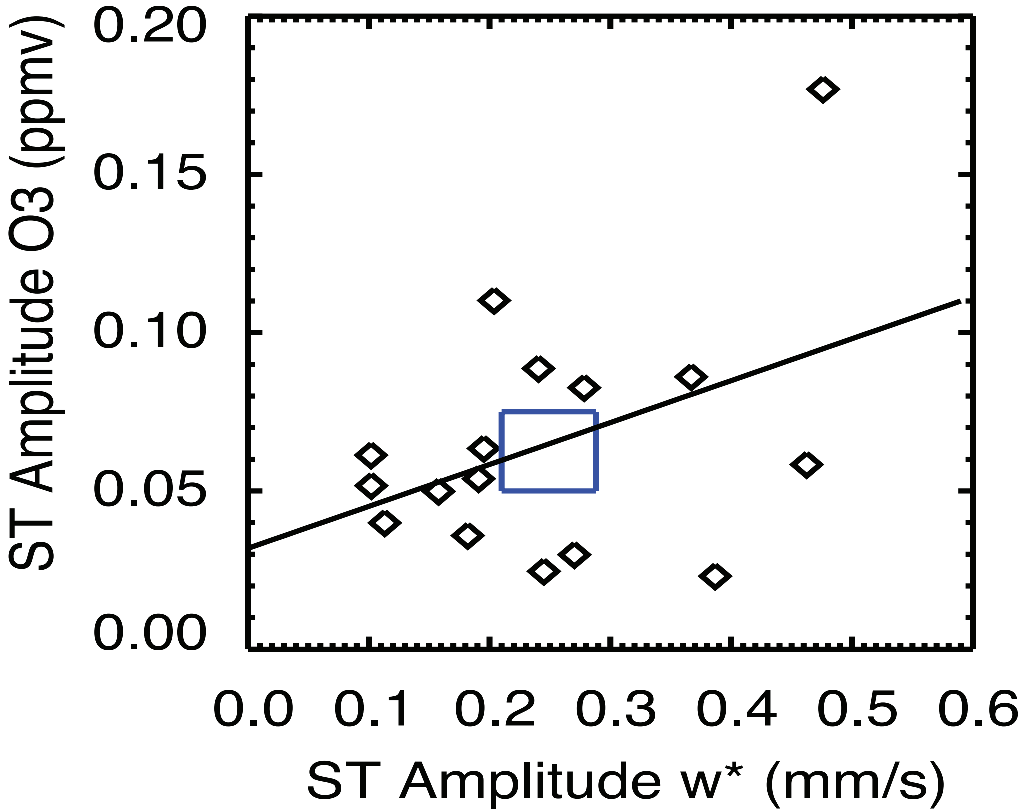
MULTI-MODEL COMPARISON

Do Chemistry Climate Models (CCMs) capture the observed differences between NT and ST?



- Distinguished between **NT** (0-20^{o}N) and **ST** (0-20^{o}S)
- In most of CCMVal-2 models NT amplitude > ST amplitude.
- Large spread in amplitudes among models.

Does seasonality in upwelling explain seasonality in ozone?



ST: spread in w* amplitude among CCMVal-2 models "explains" most of spread in O_3 amplitude

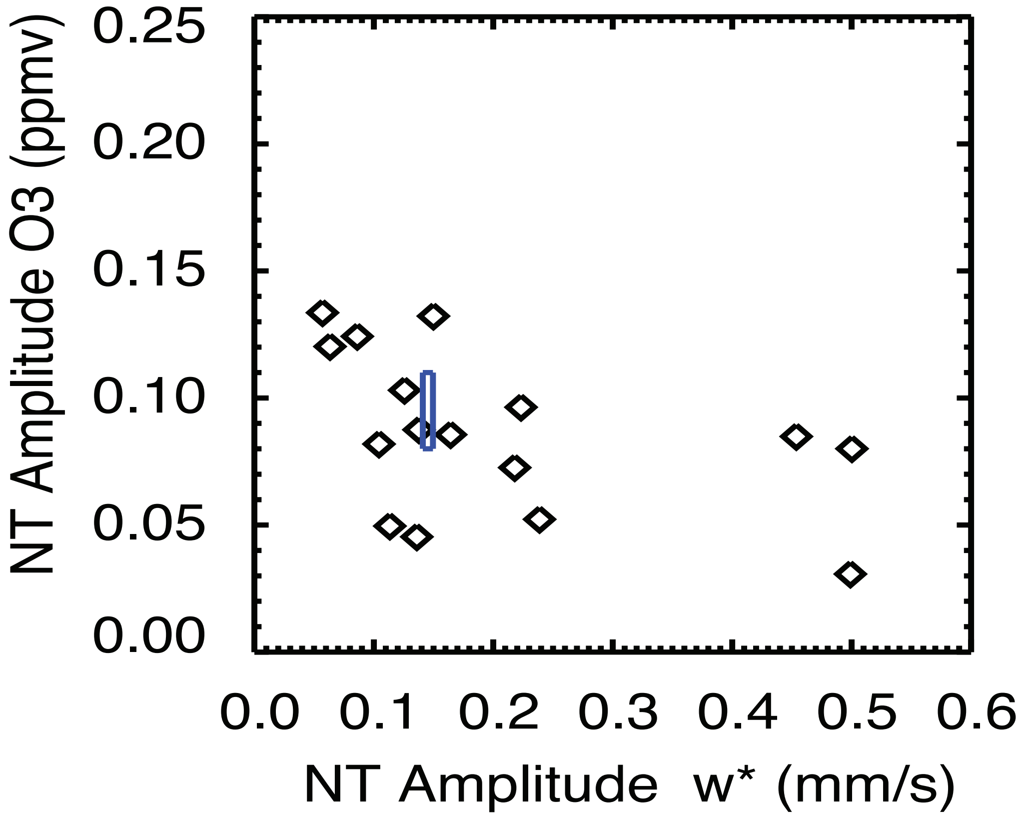
Conclusion: upwelling is controlling factor in the **ST**

Range of amplitudes in O_3 from observations and w* from reanalysis

Does seasonality in upwelling explain seasonality in ozone?

NT: no relationship between w* amplitude and O_3 amplitude among CCMVal-2 models.

Conclusion: other factors determine ozone seasonality (mixing may be more important)



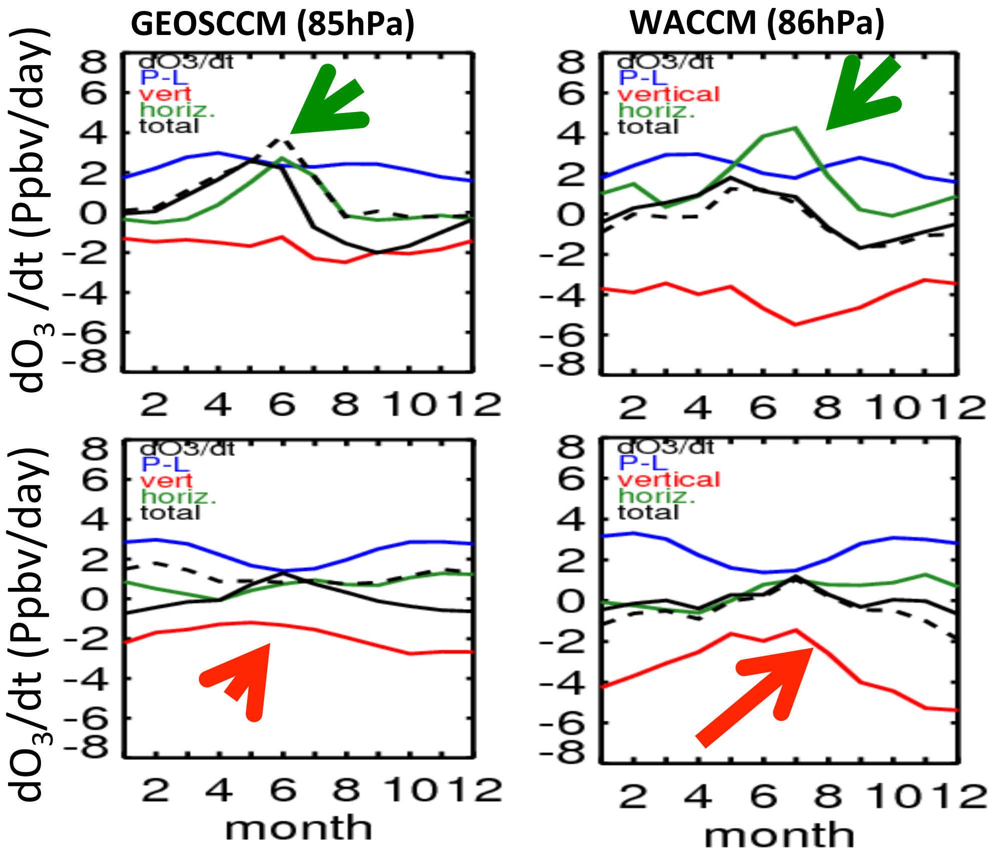
Quantifying transport affects on ozone seasonality

1. Two models from CCMVal-2 project: **WACCM** and **GEOSCCM**
2. Distinguished between **NT** (0- 18^{o}N) and **ST**(0-18^{o}S)
3. Transform Eulerian Mean analysis (**TEM**) [Andrews, 1987]:

$$\bar{\chi}_t = \boxed{\left[-\bar{v}^* \bar{\chi}_y + e^{z/H}(\cos\varphi)^{-1}(M_y \cos\varphi)_y\right]} + \boxed{\left[-\bar{w}^* \bar{\chi}_z + e^{z/H}(M_z)_z\right]} + \boxed{P - L.}$$

-to isolate role of vertical transport (red), horizontal transport (**green**), and chemistry (**blue**).

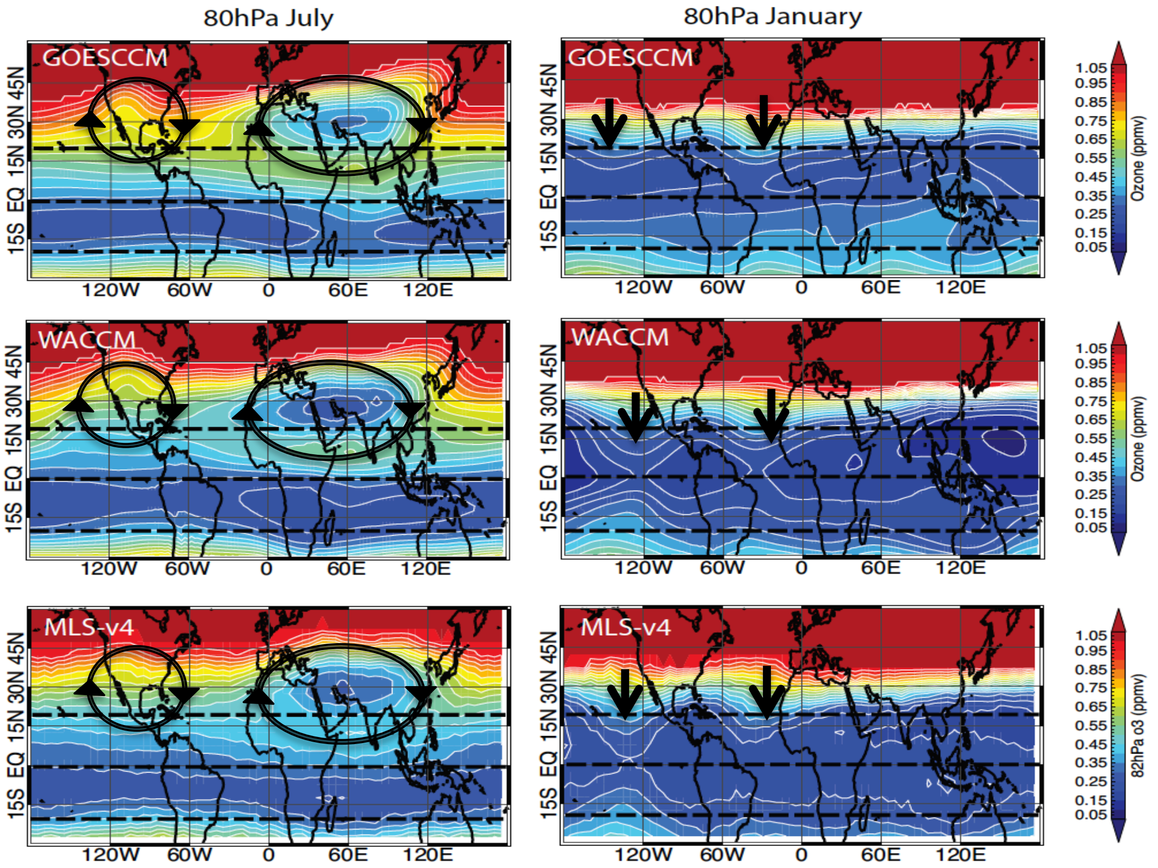
Processes controlling the NT and ST annual cycles



- **NT** – horizontal mixing is a dominant cause of seasonality
- **ST** – upwelling is a dominant cause of seasonality

$$\bar{\chi}_t = \left[-\bar{v}^* \bar{\chi}_y + e^{z/H}(\cos\varphi)^{-1}(M_y \cos\varphi)_y\right] + \left[-\bar{w}^* \bar{\chi}_z + e^{z/H}(M_z)_z\right] + P - L.$$

Zonal variations in annual cycle amplitude



- **July:** Inflow of ozone rich air from NH extratropics into the tropics by N. American and Asian Summer Monsoon

- **January:** Ozone is mixed into the tropics over Atlantic and Pacific oceans by Rossby wave breaking

CONCLUSIONS

- Paradigm of well-mixed tropics have to be reconsidered
- The majority of the CCMs produced the observed feature of a larger annual cycle in the NT than ST
- The spread among the models much larger than in observations suggesting large differences in transport among the models

- NT-ST contrast is due to differences in balance between transport processes:
    - Seasonality in upwelling is most important in the ST
    - Seasonality in horizontal mixing – in the NT.

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation Graduate Research Fellowship Program (NSF GRFP)

Authors are grateful to M. Abalos for providing them with the WACCM data

Thank you! Questions?

REFERENCES

- Garcia *et al*. (2007), Simulation of secular trends in the middle atmosphere, J. Geophys. Res., 112, D09301, doi:10.1029/2006JD007485
- Konopka *et al.* (2010), Annual cycle of ozone at and above the tropical tropopause: Observations versus simulations with the Chemical Lagrangian Model of the Stratosphere (CLaMS), Atmos. Chem. Phys., 10(1), 121–132, doi:10.5194/acp-10-121-2010
- Pawson, *et al.* (2008), Goddard Earth Observing System chemistry-climate model simulations of stratospheric ozone-temperature coupling between 1950 and 2005, J. Geophys. Res., 113, D12103, doi:10.1029/2007JD009511.
- Stolarski *et al.* (2014), Seasonal variation of ozone in the tropical lower stratosphere: Southern tropics are different from northern tropics, J. Geophys. Res. Atmos., 119, doi: 10.1002/2013JD021294
- Andrews, D. G., Holton, J. R., and Leovy, C. B.: Middle Atmosphere Dynamics, Academic Press, Orlando, Florida, 489 pp, 1987